Modeling an HF NVIS Towel-Bar Antenna on a Coast Guard Patrol Boat
A Comparison of WIPL-D and the Numerical Electromagnetics Code (NEC)

Darla Mora, Christopher Weiser and Michael McKaughan
United States Coast Guard Academy
Department of Engineering
Electrical and Computer Engineering Section
27 Mohegan Avenue
New London, CT. 06320-8101
mmckaughan@exmail.uscga.edu

Abstract
A Coast Guard patrol boat high-frequency (HF) near-vertical incident skywave (NVIS) antenna is selected as a test case to compare the electromagnetic modeling programs Numerical Electromagnetics Code, NEC and WIPL-D code. Differences between the models and program outputs will be presents. The radiation pattern predictions will be compared. Agreement between the results is found to be good. Minor adjustments of the two coordinate systems of the programs are necessary. A summary of the comparison is presents.

Introduction
At the United States Coast Guard Academy, we have used the Numerical Electromagnetics Code (NEC) for antenna analysis and design for more than twenty years.[1] During this time, we have become accustom to the output produced by the NEC, as well as the "tricks of the trade" that yield results that are applicable to the real world. There have always been intricate details necessary to develop models for the NEC that have made teaching this code to undergraduates challenging. One such detail is the labor intensive process of developing a model of even simple antennas and structures. The model development process has always been tedious and frustrating for the novice antenna designer. A second shortcoming has been the tabular output from the program. Until the development of codes similar to GNEC® by Nittany Scientific[2], visualizations of radiation patterns and antenna impedance information were DOS-bound and hence difficult to manage for Windows®-literate users.

With the introduction of the modeling code, WIPL-D[3], a new alternative is available to the electromagneticist. Advantages of this code include the fact that dielectric materials can be modeled easily, plates can be used to generate structure models, and graphical presentations of the models and results are included directly in the operating environment. An important educational advantage of the WIPL-D code is ease of use. With a simple introduction, most undergraduate electrical engineering students can grasp the use of the code, and be generating models and test results with as little as 30 minutes of instruction.

With two electromagnetic codes to choose from, which one should be adopted as the standard tool of choice? To answer this question, we designed an experiment to evaluate both codes solving a typical problem of interest to the Coast Guard. This test involves analysis of a 110-foot patrol boat. A new high-frequency antenna has been proposed to excite near-vertical incident skywave (NVIS) propagation mode to provide reliable communications in the range of 50 to 500 miles around the patrol boat. This shipboard antenna was modeled using each code and the resulting radiation characteristics and driving point impedances were compared.

Methodology
Before we could compare the results of modeling a patrol boat using NEC and WIPL-D, we had to determine any differences between the modeling results. The NEC wire-grid model was generated by ARINC, Inc. and one of the authors. This model consisted of approximately 3000 segments. A significantly simpler model was available, but was not used. The WIPL-D model was generated by two undergraduate students. When completed, it consisted of approximately 15 plates, 35 nodes, and 3 wires. This model generated about 300 unknowns in its solution.

By careful observations of the two models, we determined that there were two differences in the models that had to be remedied. The first difference was that the WIPL-D model was slightly wider than the NEC model. For our analysis, we decided to not attempt to fix this difference because of its size compared to the wavelengths that we were using. The second discrepancy was more significant. The TOWEL-BAR antenna we were testing was

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 JAN 2005	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Modeling an HF NVIS Towel-Bar Antenna on a Coast Guard Patrol Boat A Comparison of WIPL-D and the Numerical Electromagnetics Code (NEC)	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **United States Coast Guard Academy Department of Engineering Electrical and Computer Engineering Section 27 Mohegan Avenue New London, CT. 06320-8101**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001846, Applied Computational Electromagnetics Society 2005 Journal, Newsletter, and Conference., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

implemented differently on each model. This was relatively simple to correct, so we adjusted the models to more closely correspond to the installation that we plan to implement. To accomplish this change, some minor adjustments were made on the grid structure of the NEC model.

The next significant area we addressed was the coordinate systems of the two modeling programs. In their own independent worlds, the results of NEC calculations are comparable to other results computed by NEC. The same is true for the WIPL-D code. However, if we want to compare NEC results to WIPL-D results, we must insure that radiation patterns are compared correctly. A significant difference between the two programs is the elevation angle patterns. WIPL-D uses the angle θ as the elevation above the horizon ($\theta = 0°$ is the horizon and $\theta = 90°$ is the zenith). NEC calculates radiation patterns using the mathematical convention for spherical coordinates where $\theta = 0°$ is the zenith and $\theta = 90°$ is the horizon. To accommodate this difference, we had to re-define our zenith or elevation angle so they agreed for a given comparison. This was easily accomplished using a spread-sheet program.

An additional area of concern has to do with relative signal strengths computed between the two programs. Other issues of interest were methods of calculating overall antenna efficiencies. We continue to investigate these two areas.

Results and Analysis

The visualizations of the NEC and WIPL-D models are shown in Figures 1 and 2. One can see the similarity of these models. They appear to be models of the same ship. Typical radiation patterns from each program are presented in Figures 3 and 4. The radiation patterns shown in these figures were computed at frequencies of 3.0 and 12.0 MHz respectively. The specific pattern cut is for an elevation angle of 45°. Notice particularly the locations and depths of the nulls in the patterns shown in Figure 4.. This is a good indication of the agreement between the NEC and WIPL-D results. We have compared additional patterns and the antenna driving point impedances calculated by each program.

Discussion

Over the life of the NEC considerable effort has been invested in validating the predictions of this code. As a result of this investment, modelers are confident of the results of their modeling efforts, and the accompanying attention to feed point details. The authors believe it would be prudent to invest an equal energy in validating the WIPL-D predictions. Such an undertaking will increase our confidence in the predictions generated by WIPL-D.

Conclusions

A Coast Guard patrol boat high-frequency NVIS antenna was chosen to compare the electromagnetic modeling programs NEC and WIPL-D. Differences between the models and program outputs were presents. The radiation pattern predictions have been compared with good agreement. Minor adjustments between the coordinate systems of the two programs had to be accounted for. Antenna driving point impedance predictions will be included in the full presentation. Based on results presented, one can state that both NEC and WIPL-D give comparable results. Because of the ease of learning to use the WIPL-D code for undergraduate electrical engineering students, we will continue to invest our efforts in validating this code in our laboratory.

Disclaimer

The opinions expressed in this presentation are solely those of the authors and in no way reflect official policy of the United States Coast Guard or the Department of Homeland Security.

Acknowledgements

We would like to acknowledge Mr. Terry Vogler of ARINC for his help in constructing the NEC models for the patrol boat, Dr. Michael McKaughan for his assistance and prodding, and the other electrical engineering faculty members at the Coast Guard Academy for their inspiration in our pursuit of academic excellence.

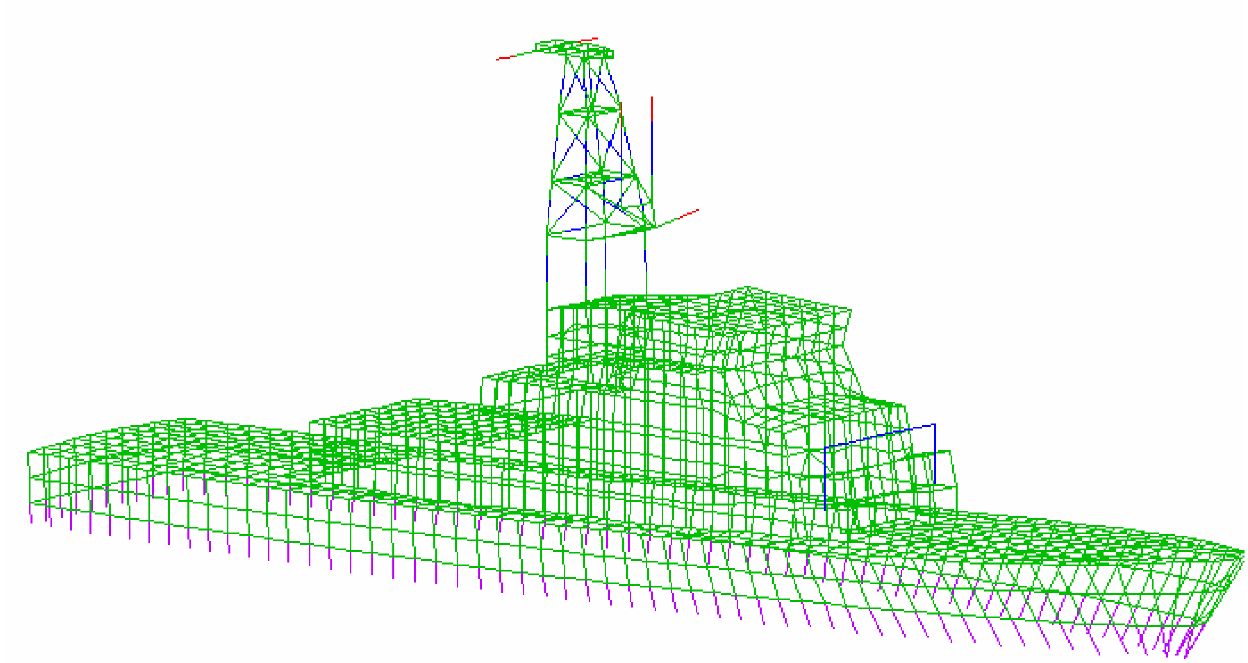

Figure 1. A visualization of the NEC model of the 110-ft patrol boat with towel bar antenna (generated using GNEC®).

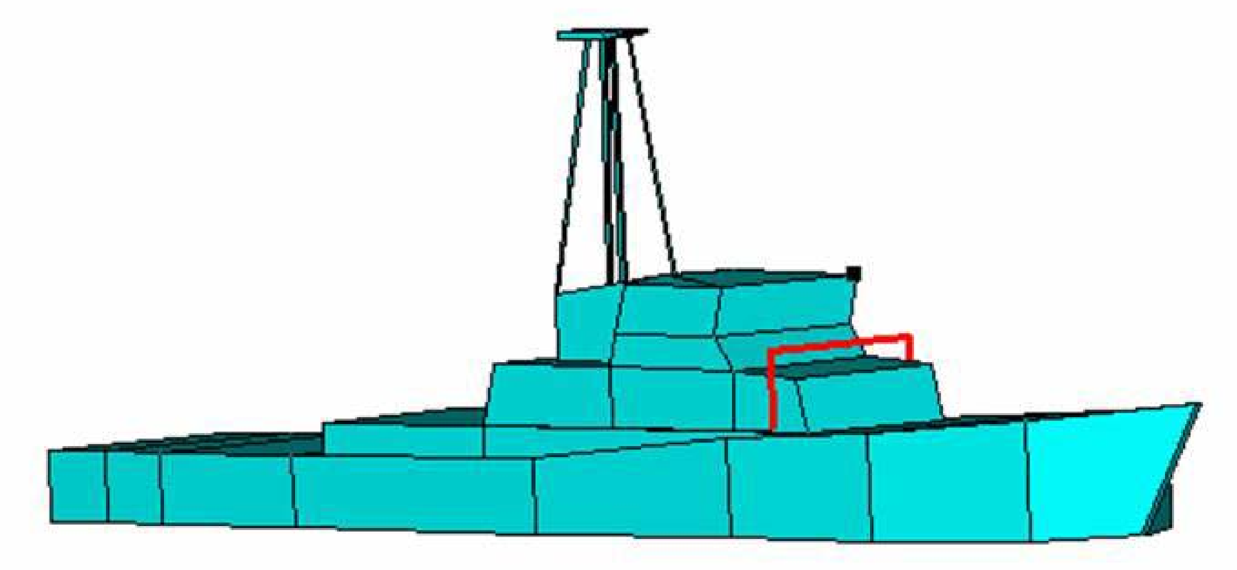

Figure 2. A visualization of the WIPL-D® model of the 110-ft patrol boat with towel bar antenna (generated as part of the WIPL-D® output).

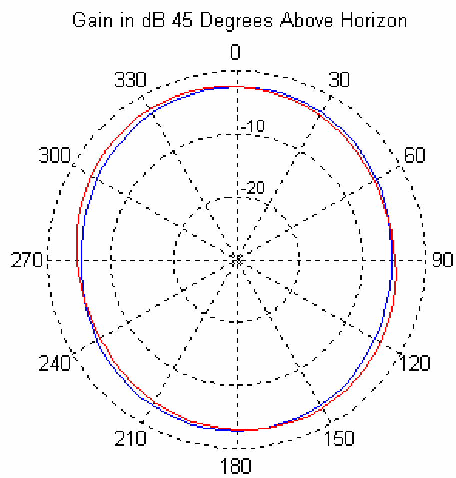

Figure 3. Predicted radiation patterns for the towel bar antenna at 3 MHz at an elevation angle of 45 degrees above the horizon. The blue line represents the results from WIPL-D® while the red line represents the results from the NEC.

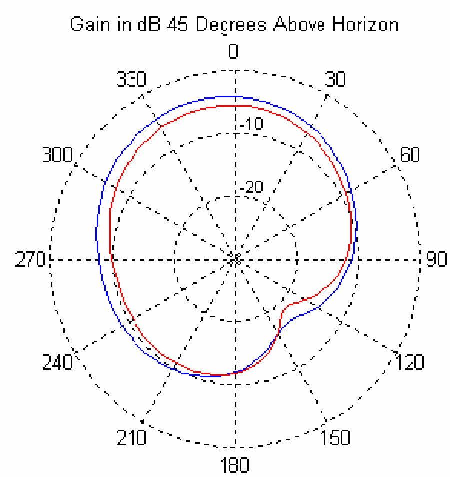

Figure 4. Predicted radiation patterns for the towel bar antenna at 12 MHz at an elevation angle of 45 degrees above the horizon. The blue line represents the results from WIPL-D® while the red line represents the results from the NEC.

References

1. McKaughan, M. E., "Coast Guard Applications of NEC," IEEE APS 2004, Monterey, CA.
2. ______, "Nittany Scientific Website" available from: www.nittany-scientific.com/ (accessed 24 November 2004)
3. Kolundžija, B. M., Ognjanovic´, J. S., Sarkar, T. K., "*WIPL-D: Electromagnetic Modeling of Composite Metallic and Dielectric Structures, Software and User's Manual,*" Artech House, 2000, Boston, MA.